Diversity, Distribution and Conservation of Freshwater Crayfishes in the Eastern Highlands of New South Wales

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The biology of most of the indigenous parastacid crayfishes inhabiting the highlands of New South Wales is poorly known, but many species have very limited ranges. Analysis of these distributions in relation to the National Parks and State Forests shows that most species are protected in reserves; however, around and within these areas a large number of potential polluted sites have been identified.

The effects of clearing, longstanding salmonid stocking and the potential problems of recent widespread introductions of non-indigenous *Cherax* species for aquaculture are discussed.

Recommendations for conservation and future management include: biological programmes to provide data on environmental preferences, interactions between indigenous and non-indigenous crays and influences of introduced salmonids; restoration and maintenance of riparian zones; surveys of polluted sites in, or adjacent to, very small ranges with initiation of remedial measures where necessary; more active policing of quarantine measures at aquaculture facilities; development of comprehensive, workable and enforceable policy on translocations; implementation of eel control measures at large impoundments on eastern drainages.

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INTRODUCTION

The Australian cray fauna is second only to North America in numbers of species and diversity; taxonomic investigations are continuing but approximately 100 species, assigned to nine genera, are currently recognised. The majority of these endemics is concentrated in the south-eastern part of the continent — especially in highland areas — and the biology of most species is very poorly known (Merrick, 1993: 5, 35-36).

New South Wales Crayfish Fauna

In New South Wales the indigenous crayfish fauna comprises at least 27 species — two in the genus *Engaeus*, four in *Cherax* and 21 in *Euastacus*; further new species and subspecies of this latter group have been recognised but formal descriptions have not yet been published. In addition, three other *Cherax* species have been widely introduced for aquaculture (Merrick, 1993: 39). Table 1 below lists all freshwater crayfishes currently recognised in this state together with remarks on known ranges.

Clearly the New South Wales fauna is dominated by *Euastacus* species which almost all inhabit highlands or streams near elevated areas; other *Euastacus* species dominate south-eastern Queensland and Victorian highlands. After revisionary studies this genus of spiny crays has become the largest in the family Parastacidae (Morgan, 1986, 1988, 1989, 1991). Hence this paper will be primarily considering the conservation of *Euastacus* species; the investigation is focussed on New South Wales but similar situations exist elsewhere. Several additional environmental modifications are known to affect the *Cherax* species inhabiting coastal lowlands (Merrick, 1993: 94) but will not be considered further here.

TABLE 1.
Freshwater crayfishes indigenous to New South Wales (based on Merrick, 1993: 40-82).

Genus, Species	Distribution, Remarks
* *Cherax cuspidatus*	Extended range, mostly coastal lowlands
C. destructor	Wide inland range, extends to foothills
C. neopunctatus	Extended coastal lowland range
C. rotundus	Extensive range, includes both coastal plain and highlands
# *Engaeus cymus*	Extensive range, to altitudes >1,000 m
E. orientalis	Extensive range, variety of highland habitats
Euastacus alienus	Very restricted range (upper Karuah R. system)
E. aquilus	Very restricted range (east of Armidale)
E. armatus	Extensive range, mostly inland lowlands but to >700 m
E. australasiensis	Limited range (Illawarra, Blue Mtns, Gosford districts)
E. bidawalus	Limited range (150-400 m altitude)
E. brachythorax	Limited range (Tuross R. basin)
E. claytoni	Extensive range
E. clydensis	Limited range including coastal lowlands
E. crassus	Extensive range
E. hirsutus	Very limited range (Illawarra coastal streams)
E. keirensis	Very restricted range (Mt Keira)
E. neohirsutus	Very restricted range (inland of Coffs Harbour)
E. nobilis	Very limited range (Parramatta, Hawkesbury R. systems)
E. polysetosus	Restricted range (upper Hunter, Manning R. systems)
E. reductus	Very restricted range (upper Hunter R. system)
E. simplex	Restricted range (upper Macleay, Clarence R. systems)
E. spinifer	Limited range (Blue Mtns, Illawarra)
E. spinosus	Restricted range (Hastings, Camden-Haven R. systems)
E. sulcatus	Limited range, altitudes >300 m
E. suttoni	Extensive range, altitudes >680 m
E. valentulus	Extended coastal range, lowlands to 600 m altitude

* Three additional non-indigenous *Cherax* species (*C. albidus, C. quadricarinatus, C. tenuimanus*) have been widely introduced for commercial culture.
# These are land crayfishes but occur in highland areas.

Natural Ranges, Reserves, Aquaculture and Pollution

Many *Euastacus* species have very small, discrete distributions and a number of long-term, environmental factors that have contributed to this zoogeographic pattern are discussed by Dodson *et al.*, (1992) and Ross *et al.*, (1992). For a description of the wild highland aquatic habitat see Merrick and Schmida (1984: 15, 17).

These small, remote ranges make these crayfishes both susceptible to local disasters and difficult to monitor (Merrick, 1993: 15). Although the eastern highlands are where the majority of National Parks and State Forests are sited, the substantial development and environmental modification in eastern New South Wales has only been partially balanced by the declaration of new reserve areas.

These crays, which are generally slow to mature with low fecundities, are in the same areas where trouts have been cultured and stocked for many years; these salmonids are limited to the highlands by thermal tolerances. In addition there has been considerable expansion of other types of freshwater aquaculture in recent years (Merrick, 1992). A recent review shows that 105 farms are registered to produce 10 species of freshwater crayfish in all except the far north-western river basins (e.g. Paroo River); many of these facilities are producing non-indigenous crays — either to New South Wales or the particular area of the state. Most facilities are very small with low production and part-time management. About 20 farms, concentrated in the south-east, produce four species of salmonid (Merrick, 1992).

Recognition of the degradation of Australian freshwater environments has coincided with the political acknowledgement of the importance of environmental issues — in particular the maintenance of biodiversity and ecologically sustainable development (Ecologically Sustainable Development Working Groups, 1991). Problems in freshwaters have been developing for many years (Lake, 1978) but the recent widespread blue-green algal blooms have elevated the issues into a high priority category (Creagh, 1992; Hart, 1992). A number of water quality problems have been recognised throughout New South Wales (Water Resources Commission, 1986) and many potentially polluted sites identified; some 60,000 sites are considered to require investigation and 7,000 of these possibly require remedial action (Grant, 1992).

Biology and Management

Although not as well known as vertebrate groups it has become increasingly clear that crayfishes are of prime importance in many aquatic ecosystems, in terms of biomass and energy transfer (Hogger, 1988). Fortunately, there are no records of introductions of exotic (non-Australian) crayfishes (Thomson *et al.*, 1987; Holdich, 1993) and, although no endemics are considered endangered at present a number of *Euastacus* species have been classified as threatened (Horwitz, 1990). There are few data on the ecology of relatively undisturbed wild populations, but even less is known about the interactions of native crays with non-indigenous crays or other introductions such as fishes (Courtenay, 1990; Merrick, 1992).

As with other environments, management decisions relating to aquatic habitats have often been taken on the basis of the better known vertebrates — usually fishes. Recent research has provided some information on habitat preferences and requirements of at least the larger or dominant fish species (Mallen-Cooper, 1989); but there are still no data on the relative importance of snags (submerged logs, fallen branches or roots protruding from under banks) or other environmental factors for invertebrates.

The objectives of this paper are: to compare known ranges of native crays in New South Wales highlands with the distributions of reserves and registered aquaculture facilities; to discuss these patterns, generally, in relation to known polluted sites and water quality problems; to summarise the data on apparent habitat preferences; to identify high priorities for immediate research and discuss potential problems; to combine existing biological and environmental data in the formulation of recommendations for the conservation of the crayfish fauna.

Materials and Methods

Natural Ranges, Reserves, Aquaculture and Pollution

Species ranges are illustrated together with the extent of National Parks, State Forests and other reserves as well as the distribution of culture facilities (Figures 1, 2). Key data on aquaculture facilities are summarised (Tables 2, 3) and comments on polluted sites are also included.

Biology and Management

Aspects of the biology and environmental requirements of native crays particularly relevant to conservation management are summarised. Management problems and high priority areas for urgent attention are identified and options considered. Finally detailed recommendations, both for immediate and progressive long-term implementation, are formulated.

Results

Natural Ranges, Reserves, Aquaculture and Pollution

Figures 1 and 2 demonstrate several general points. Firstly, the ranges of most cray

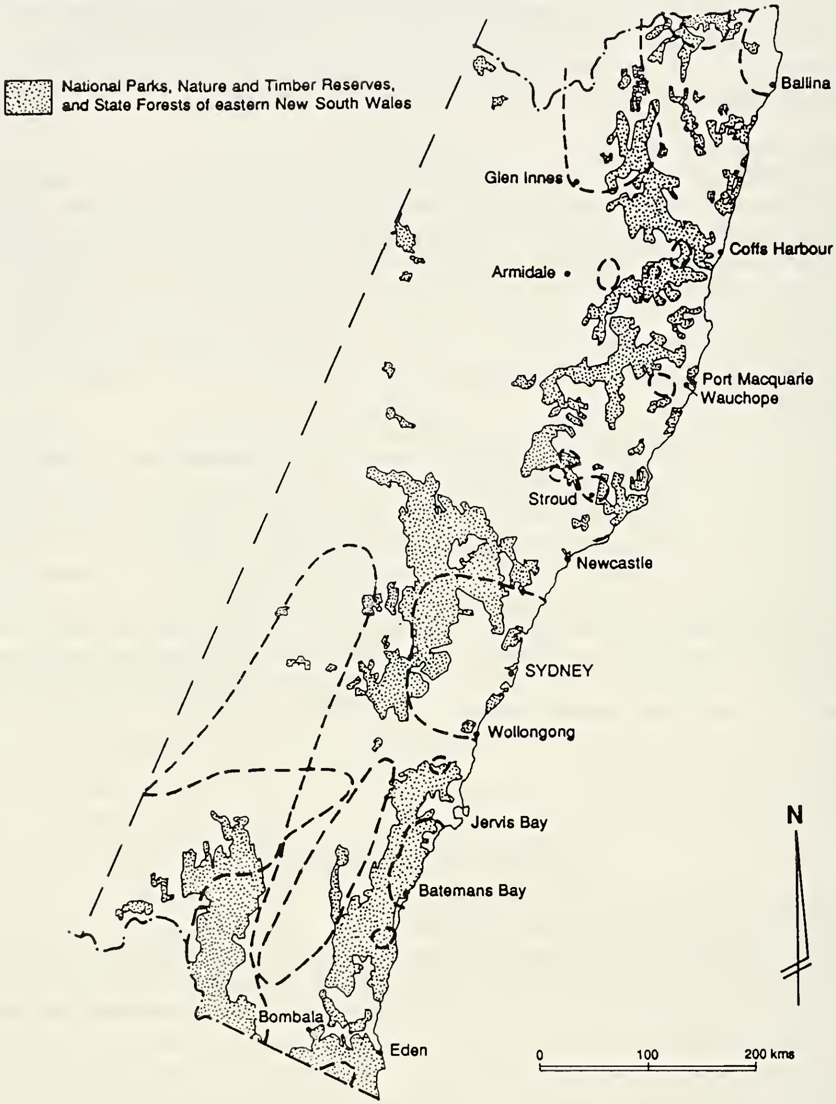

Fig. 1. National Parks, Nature and Timber Reserves and State Forests of eastern New South Wales (stippled) with natural ranges of 21 endemic *Euastacus* species marked (outlined). Range outline around Sydney includes reported distributions for four species. Based on Forestry Commission of New South Wales (1991), Riek (1969) and Merrick (1993).

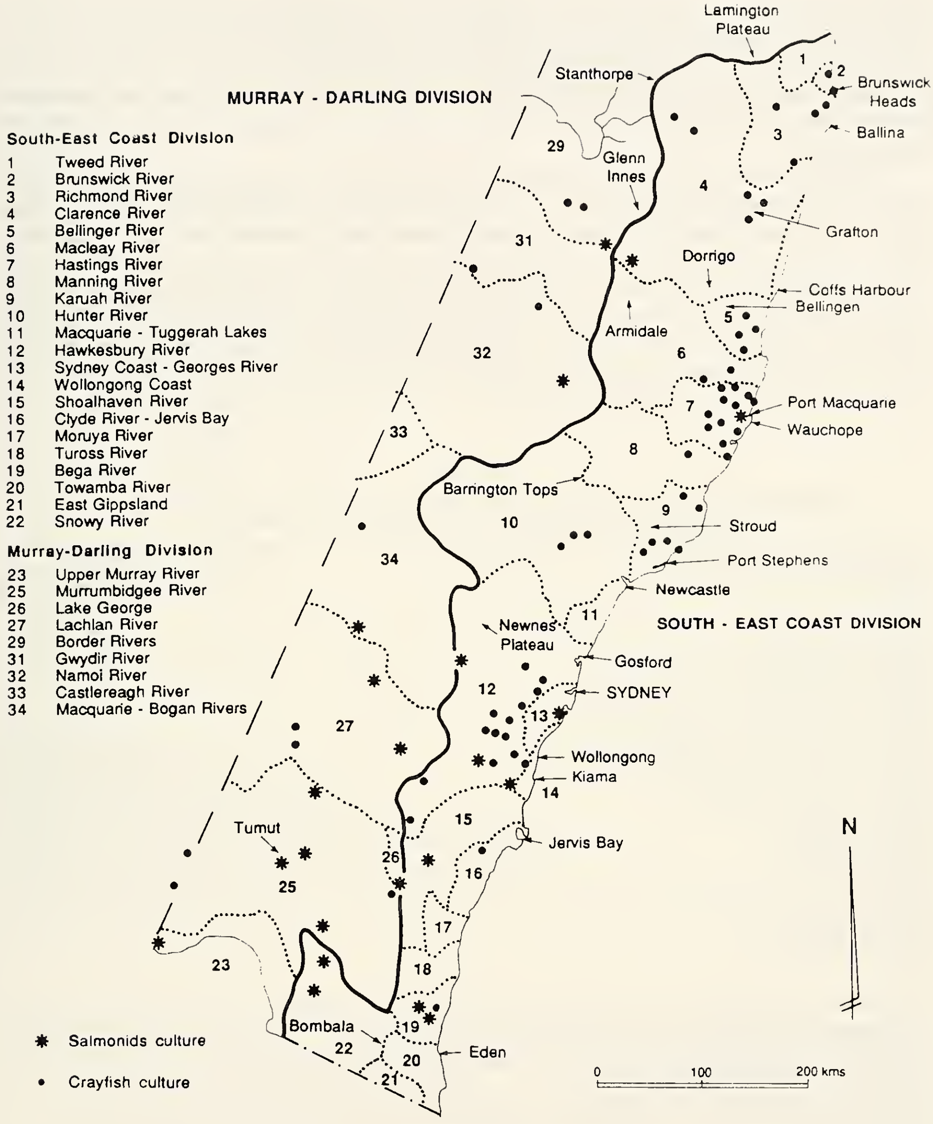

Fig. 2. Drainage Divisions and Basins of eastern New South Wales with approximate localities of most aquacultural facilities marked (N.S.W. Fisheries, unpublished data). Some salmonid farms also produce crayfish. Key to facilities: (•) crayfish culture; (*) salmonid culture.

species are included in, or at least partially overlap, reserves. Secondly, the majority of aquaculture facilities are sited on, or east of, the dividing range. Facilities in eastern drainage basins are clustered in three areas: the northernmost cluster extends from just south of the border to the Grafton area; the largest cluster extends from Bellingen south to Port Stephens; a third, smaller group extends from west of Sydney to inland of Kiama. Finally, water quality problems have been identified in a number of areas — including upper reaches.

Tables 2 and 3 demonstrate that crayfish farms comprise the biggest single category of facility (about 40% of the total) — with another 25% producing some crays in combination with other organisms. Over 50% of all cray farms are east of the Dividing Range (Figure 2) and a majority produce two or more species. While 49 farms produce *C. destructor* only, another 41 culture some of this species. Redclaw (*Cherax quadricarinatus*) is produced by 40 farms but only eight are solely dependent on this species. Of the 20 farms registered to produce marron only three culture it exclusively. The seven *Euastacus* farms are all within or adjacent to the natural range of the particular species. Trout and salmon farms comprise another significant category (about 14%) of aquaculture facilities.

TABLE 2.
Registered aquaculture facilities in New South Wales (1992) grouped on the basis of organisms cultured — oyster leases not included (based on N.S.W. Fisheries, unpublished data).

Categories of Organisms Cultured	No of Farms*
Crayfishes	65
Crayfishes + Native Fishes	16
Crayfishes + Native Fishes + Salmonids	3
Crayfishes + Salmonids	3
Crayfishes + Native Fishes + Aquarium Fishes	7
Crayfishes + Native Fishes + Shrimps	2
Crayfishes + Native Fishes + Shrimps + Mussels	3
Crayfishes + Native Fishes + Mussels + Prawns	1
Crayfishes + Shrimps + Mussels	2
Crayfishes + Mussels	1
Crayfishes + Prawns	1
Crayfishes + Shrimps	1
Prawns	8
Prawns + Oysters	4
Prawns + Native Fishes	1
Crab	1
Native Fishes	17
Native Fishes + Salmonids	2
Salmonids	13
Native Fishes + Aquarium Fishes	3
Native Fishes + Aquarium Fishes + Salmonids	1
Aquarium Fishes	8
Total farm licences	163

* A large majority of facilities (126) have a hatchery capacity, but whether it is currently in use is unknown (Rayns, 1992, personal communication); 37 farms are grow-out areas only.

Although many polluted sites have been identified, data on exact locations, or risk status, are not freely available. A state-wide register is being compiled by the Environment Protection Authority (EPA) of New South Wales and Local Governments have lists of known polluted sites in their areas — for reference in response to specific requests (McFarland, 1993, personal communication).

TABLE 3.
New South Wales crayfish farms and trout farms (1992) grouped on the basis of species cultured (based on N.S.W.Fisheries, unpublished data).

Combination of Species per Farm	**No of Farms***
(a) Crayfishes	
Cherax destructor	49
Cherax destructor + C. quadricarinatus	16
Cherax destructor + C. quadricarinatus + C. tenuimanus	7
Cherax destructor + C. quadricarinatus + C. tenuimanus + C. albidus	1
Cherax destructor + C. quadricarinatus + C. albidus	1
Cherax destructor + C. quadricarinatus + C. albidus + C. rotundus	1
Cherax destructor + C. quadricarinatus + C. rotundus	1
Cherax destructor + C. quadricarinatus + C. rotundus + E. valentulus	1
Cherax destructor + C. quadricarinatus + E. valentulus	1
Cherax destructor + C. tenuimanus	6
Cherax destructor + C. tenuimanus + C. albidus	1
Cherax destructor + C. tenuimanus + E. armatus	1
Cherax destructor + C. rotundus	1
Cherax destructor + C. rotundus + C. cuspidatus	1
Cherax destructor + E. armatus	2
C. quadricarinatus	8
C. quadricarinatus + C. tenuimanus	1
C. quadricarinatus + Euastacus sp.	1
C. quadricarinatus + E. spinifer	1
C. tenuimanus	3
C. albidus	1
Total farms producing crayfishes	105
(b) Salmonids	
Oncorhynchus mykiss	15
Oncorhynchus mykiss + Salmo trutta	2
Oncorhynchus mykiss + Salmo salar	1
Oncorhynchus mykiss + Salmo trutta + Salmo salar	1
Oncorhynchus mykiss + Salmo trutta + Salmo salar + Salvelinus fontinalis	3
Total farms producing salmonids	22

A detailed survey of all suspected polluted sites in the highlands was beyond resources for this study; however, preliminary investigations revealed the following:

(a) register records are still incomplete — for example, EPA has no information on the southern highlands of the State;
(b) among identified sites the risk varies enormously — some cattle dip sites are considered low risk;
(c) the major pollutant from agricultural land is the metal Arsenic — wherever a tannery has been established there is residual pollution (usually Arsenic) (McFarland, 1993, personal communication);
(d) over 1,100 sites are currently registered as mines in New South Wales and this does not include many small workings, in the highlands, long since abandoned (Woodside, 1993, personal communication);
(e) comparisons of *Euastacus* distributions with EPA records did not reveal any significant threats in most highland areas, but there are some polluted 'hot spots' in the *E. australasiensis* and *E. spinifer* ranges (McFarland, 1993, personal communication).

Biology and Management

Although current data are scant a number of environmental requirements and life cycle features appear to be similar in a number of *Euastacus* species; these criteria, directly relevant to management, are drawn from Merrick (1993) and summarised below.

Highland areas known to maintain abundant endemic cray populations generally have the following characteristics. The waterway is shallow (depths 0.05 – 5.0m) with a rock, gravel and/or sand substrate; logs and leaf detritus are also present. Flow is usually continuous for most of the year, although rates may be low; dissolved Oxygen levels are high (>5 p.p.m.), pH 7.0 – 8.5, salinity <3,000 p.p.m. and turbidity low. Water temperatures range from 5° – 30°C and there is a low incidence of large, carnivorous fishes (Murray cod, trout cod, trouts, eels). Banks may be gently sloping or steep (undercut) and are shaded by native vegetation (most frequently rainforest or wet sclerophyll forest).

In addition to low growth rates and fecundities other biological features which contribute to slow recruitment include: an annual breeding (not all mature females spawn each year); a long incubation interval (4–6 months, often at low temperatures); an extended larval period (up to 2 months, sometimes in high temperatures); very limited dispersal or movement by young at release and significant predation by larger individuals on juveniles.

Discussion

Comments on the present studies and the recommendations are framed in the context of the following general observations. Firstly, the distribution patterns of crays in the eastern highlands are similar to those now being documented for other invertebrate groups, such as gastropods and oligochaetes (Dyne, 1991; Stanisic, 1994) and show strong correlations with the occurrence of rainforest (Dyne, 1991). Secondly, recent systematic studies on other invertebrate groups have revealed enormous biodiversity in environments previously considered depauperate and a complexity of faunal interactions unsuspected earlier (Campbell and Brown, 1994; Ponder, 1994). Thirdly, the system of existing and planned reserves is very limited and unlikely to be adequate to maintain current biodiversity (Pressey and Griffith, 1992). Fourthly, that with a few exceptions, conservation on a species-by-species basis is not feasible; the emphasis has to be on the conservation and management of systems or biotic/habitat complexes (Saunders, 1993). Finally, that even in the absence of comprehensive baseline data, some conservation measures can and should be taken in the immediate future.

National Ranges, Reserves, Aquaculture and Pollution

Detailed analyses of individual species ranges with respect to reserves and other features are beyond the scope of this paper and it should be noted that the only *Euastacus* species to have been translocated to any extent is *E. armatus* (Harris and Battaglene, 1989). This has the broadest of all *Euastacus* distributions and is not considered at the same degree of risk as species with very restricted ranges in eastern drainage basins.

Whilst the overlap of many highland cray ranges with existing National Parks and State Forests is reassuring in some ways, it should be emphasised that these invertebrates can still be effected by factors outside the reserves. The most important threat to *Euastacus* species appears to be clearing — for dairying or forestry — with the attendant changes in water quality and eutrophication (Merrick, 1993: 93); however, agriculture and man-made pollutants are also emerging as significant problems.

Despite the fact that most salmonid introductions have not succeeded (Clements, 1988: 289) the continued efforts of many Government, Acclimatisation Society and Club hatcheries — with repeated releases at many highland sites over a century or more — must have had considerable biotic impacts (Merrick and Rimmer, 1984; Clements, 1988:

278-289). There is now evidence that predation by trout can have local negative effects on small native fish species (Tilzey, 1976). Brown and rainbow trout quickly established in many areas, with the latter species being produced in the largest numbers in recent years (Clements, 1988: 138-140); over 20 farms are sited close to highland cray ranges.

Crayfish culture has expanded significantly in the south-east in recent years but the very features making *Cherax destructor* and *C. quadricarinatus* attractive to culture, such as frequent breeding and rapid growth, make them a potential threat. Overseas experience has repeatedly demonstrated displacement of native species by introductions that are aggressive, physiologically tolerant, grow quickly and breed frequently (Hogger, 1988; Lowery and Holdich, 1988; Holdich and Rogers, 1992). There are a few observations on the effects of the introduction of *Cherax albidus* to south-western Western Australia (Austin, 1985); but no studies have been published on the widespread introduction in eastern Australia of *Cherax destructor, C. quadricarinatus* or *C. tenuimanus.* The various potential environmental problems associated with translocations and aquaculture have been well documented elsewhere (Courtenay, 1990; Merrick, 1992), but the disturbing feature of this situation is the possibility that cray culture and the presence of trouts could act synergistically, with other factors, to contribute to the decline of isolated, indigenous populations. Over 80 facilities are sited adjacent to highland cray ranges.

Although less modified than most areas National Parks and State Forests could still contain possibly point sources of pollution and are subject to the effects of previous mismanagement elsewhere in the catchment. The implementation of Total Catchment Management Plans should, in future, minimise problems but old abandoned mine-sites with tailings or slag heaps are a continuing cause for concern. They are often close to streams and heavy rain can cause sudden leaching of high concentrations of metal, or other inorganic ore-processing chemicals, into the waterway. The numerous, long-term effects of mining on aquatic resources, together with the widespread impacts from individual mines, have been well documented (American Fisheries Society Water Quality Section Committee, 1988). Standards required for water quality parameters should be based on the recent recommendations of the Australian and New Zealand Environment and Conservation Council (1992).

Although major parts of the natural ranges of *E. australasiensis* and *E. spinifer* are now urban and industrial areas associated with Sydney, with all the attendant pollution problems, reduced populations of both species should persist. Fortunately, these *Euastacus* are present in long-established National Parks ringing the metropolitan area and many populations inhabit small, discrete, local catchments; these habitats are buffered, to some extent, from the environmental modification occurring in adjacent drainages.

Biology

Biological knowledge of all highland crays is totally inadequate for sustainable management; baseline date on all aspects of life cycles are required. Interspecific interactions may be very important, although Tasmanian studies suggest that sympatric indigenous species segregate within the same habitat and have relatively little contact (Richardson and Swain, 1980).

Another aspect of interspecific interaction which needs attention is that of predation. Measures for controlling eel populations may be necessary. With increasing impoundment of eastern streams large new habitats are being created that are favourable for eels — especially the large, long-finned eel (*Anguilla reinhardtii*). Eels are particularly effective predators on crays (Cukerzis, 1988); for a description of a local situation where eels have become a dominant predator in impoundments, with a summary of active and passive population control options, see the study of Merrick and Rimmer (1984).

Preferred environments for these crays can only be maintained if bank areas remain intact. In many cases these zones are rainforests and recent research has shown that this community type is very badly effected by fire (Friederich, 1991).

Management Recommendations

The initiatives suggested below are designed: to be implemented (where appropriate) both within reserve boundaries and elsewhere; to provide further time in which to concentrate on identified priority research areas; to complement and supplement existing initiatives, such as Landcare, Fishcare or National Parks and Wildlife Service Biodiversity Conservation Strategies. The order of listing does not indicate relative importance or imply a necessary sequence — all measures can be concurrent.

1. Biological research programmes should be initiated immediately on all crays native to the highlands. These studies will have three general aims: (a) to provide baseline biological data; (b) investigate habitat preferences and interactions between native and non-indigenous crays; (c) examine interactions between native crays and the introduced salmonids.
2. Where possible restoration of aquatic habitat should commence; further de-snagging, channelisation or impoundment of headwaters should not be permitted. Where an existing impoundment structure is redundant or unsound its removal should be considered.
3. Surveys of water quality and potential polluted sites — particularly in or adjacent to small ranges — are needed. Where problems are detected measures should then be initiated to reduce them to within recommended limits.
4. Prohibit stocking or any non-indigenous aquatic species to headwaters where an endemic cray with a limited range is known to occur; where stockings of mobile non-indigenous organisms, such as trouts, are required downstream any re-stocking above natural barriers should cease.
5. Restoration of cleared or damaged stream banks should commence immediately; riparian strips of natural vegetation should be maintained (at least 100m wide). There are several aspects to this:
   - i controlling dieback where it occurs in existing riparian stands;
   - ii replanting with natives and continued weeding of exotics; where rainforest is involved an additional buffer zone of sclerophyll timbers may be necessary to minimise edge affects;
   - iii eliminating access by livestock to riparian zones and watercourses; this will require fencing in some areas;
   - iv active control of feral organisms — especially large animals such as horses, pigs and goats;
   - v monitoring and effective protection of riparian zones from bushfires.
6. Strict controls on all recreational activities are required and all fisheries for larger species should be converted to a sport category with appropriate regulations — such as those applied now to the Murray crayfish (*Euastacus armatus*). These regulations may have to vary between different areas to suit particular species or populations.
7. Further culture of non-indigenous cray species should be discouraged; and a more effective and comprehensive translocation policy developed.
8. Frequent inspections of all aquaculture facilities should be mandatory — checks on disease occurrence and control procedures, waster-water treatment and security measures such as screening or fencing should be especially rigorous.
9. Passive and active eel control measures should be instituted on large impoundments on eastern drainages.
10. Using a combination of watercourse and riparian features (physicochemical parameters, habitat diversity, food resources, types and occurrence of predators) as well as other biological data (physiological tolerances, life cycle) a predictive system should be developed. This assessment would be designed to provide a quantitative value indicating the relative suitability of the particular habitat for stocking, or re-stocking, with a particular crayfish.

These initiatives are long-term, will require continued active input and/or monitoring and may involve a re-allocation of existing resources. Although specifically formulated to ensure the survival of crayfish stocks, the total programme involves the maintenance of entire watercourses and bank zones together with the biotic assemblage inhabiting those areas. Inaction or delay could result in irreplaceable losses.

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References

American Fisheries Society Water Quality Section Committee. 1988. — Effects of surface mining on aquatic resources in North America. *Fisheries* 13: 19-22.

Austin, C.M. 1985. — Introduction of the yabbie, *Cherax destructor* (Decapoda: Parastacidae) into southwestern Australia. *Western Australian Naturalist* 16: 78-82.

Australian and New Zealand Environment and Conservation Council. 1992. — *Australian Water Quality Guildelines for Fresh and Marine Waters.* A.N.Z.E.C.C., Canberra.

Campbell, A.J. and Brown, G.R. 1994. — Distribution of parasitoids of scarab larvae in relation to remnant vegetation: a preliminary analysis. *Memoirs of the Queensland Museum* 36: 27-32.

Clements, J. 1988. — *Salmon at the Antipodes. A History and Review of Trout, Salmon and Char and Introduced Coarse Fish in Australasia.* J. Clements, Ballarat.

Courtenay, W.R. Jnr. 1990. — Fish introductions and translocations and their impacts in Australia. *In*: Pollard, D.A. (ed.) *Introduced and Translocated Fishes and their Ecological Effects.* Pp. 171-179. Australian Society for Fish Biology Workshop: Bureau of Rural Resources Proceeding 8.

Creagh, C. 1992. — What can be done about toxic algal blooms? *Ecos* 72: 14-19.

Cukerzis, J.M. 1988. — *Astacus astacus* in Europe. *In*: Holdich, D.M. and Lowery, R.S. (eds). *Freshwater Crayfish: Biology, Management and Exploitation.* Pp. 309-340. Croom Helm Ltd., London.

Dodson, J., Fullagar, R. and Head, L. 1992. — Dynamics of environment and people in the forested crescents of temperate Australia. *In*: Dodson, J. (ed.) *The Naive Lands.* Pp. 115-159. Longman Cheshire, Melbourne.

Dyne, G.R. 1991. — Earthworm fauna of Australian rainforests. *In*: Werren, G. and Kershaw, P. (eds). *The Rainforest Legacy. Australian National Rainforests Study. Volume 2.* Pp. 335-343. Australian Heritage Commission, Special Australian Heritage Publication Series 7.

Ecologically Sustainable Development Working Groups. 1991. — *Final Report – Fisheries.* Australian Government Publishing Service, Canberra.

Forestry Commission of New South Wales. 1991. — *New South Wales State Forests and National Parks.* Map 1: 2,000,000. Second Edition. Forestry Commission of N.S.W., Sydney.

Friederich, R. 1991. — Management of rainforest in national parks and equivalent reserves in northern New South Wales. *In*: Werren, G. and Kershaw, P. (eds). *The Rainforest Legacy. Australian National Rainforests Study. Volume 3.* Pp. 216-230. Australian Heritage Commission, Special Australian Heritage Publication Series 7.

Grant, C. 1992. Insights from experience in the management of contaminated sites in New South Wales. *Fulbright Symposium Paper, Contaminated Sites in Australia: Challenges for Law and Public Policy, University of New South Wales, Sydney – 28-29 August.*

Harris, J.H. and Battaglene, S. 1989. — The translocation of freshwater fishes in south-eastern Australia. *Australian Society for Fish Biology Pre-Conference Workshop, Introduced and Translocated Fishes and their Ecological Effects.* (abstract only).

Hart, B.T. 1992. — Ecological condition of Australia's rivers. *Search* 23: 33-37.

Hogger, J.B. 1988. — Ecology, population biology and behaviour. *In*: Holdich, D.M. and Lowery, R.S. (eds). *Freshwater Crayfish: Biology, Management and Exploitation.* Pp. 114-144. Croom Helm Ltd., London.

Holdich, D.M. 1993. — A review of astaciculture: freshwater crayfish farming. *Aquatic Living Resources* 6: 307-317.

Holdich, D.M. and Rogers, W.D. 1992. — Crayfish populations in the British Isles: farming, legislation, conservation and management. *Finnish Fisheries Research* 14: 23-32.

Horwitz, P. 1990. — The conservation status of Australian freshwater crustacea. *Australian National Parks and Wildlife Service Report Series* (14): 1-121.

Lake, P.S. 1978. — On the conservation of rivers in Australia. *Australian Society for Limnology Newsletter* 16: 24-28.

Lowery, R.S. and Holdich, D.M. 1988. — *Pacifastacus leniusculus* in North America and Europe, with details of the distribution of introduced and native crayfish species in Europe. *In*: Holdich, D.M. and Lowery, R.S. (eds). *Freshwater Crayfish: Biology, Management and Exploitation.* Pp. 283-308. Croom Helm Ltd., London.

MALLEN-COOPER, M. 1989. — Fish passage in the Murray-Darling Basin. *In*: MURRAY-DARLING BASIN COMMISSION. *Proceedings of the Workshop on Native Fish Management*. Pp. 123-125. MDBC, Canberra.

MERRICK, J.R. 1992. — *Prospects for Aquaculture in New South Wales. Report 4 – Ecologically Sustainable Development.* Total Environment Centre, Sydney.

MERRICK, J.R. 1993. — *Freshwater Crayfishes of New South Wales*. Linnean Society of New South Wales, Sydney.

MERRICK, J.R. and RIMMER, M.A. 1984. — Reservoir fishes and water quality monitoring systems. Baseline studies 1981-1983. *Metropolitan Water Sewerage and Drainage Board Report.*

MERRICK, J.R. and SCHMIDA, G.E. 1984. — *Australian Freshwater Fishes. Biology and Management.* J.R. Merrick, Sydney.

MORGAN, G.J. 1986. — Freshwater crayfish of the genus *Euastacus* Clark (Decapoda, Parastacidae) from Victoria. *Memoirs of the Museum of Victoria* 47: 1-57.

MORGAN, G.J. 1988. — Freshwater crayfish of the genus *Euastacus* Clark (Decapoda, Parastacidae) from Queensland. *Memoirs of the Museum of Victoria* 49: 1-49.

MORGAN, G.J. 1989. — Two new species of the freshwater crayfish *Euastacus* Clark (Decapoda: Parastacidae) from isolated high country of Queensland. *Memoirs of the Queensland Museum* 27: 555-562.

MORGAN, G.J. 1991. — The spiny freshwater crayfish of Queensland. *Queensland Naturalist* 31: 29-36.

PONDER, W. 1994. — Austraian freshwater molluscs: conservation priorities and indicator species. *Memoirs of the Queensland Museum* 36: 191-196.

PRESSEY, R.L. and GRIFFITH, S.J. 1992. — Vegetation of the coastal lowlands of Tweed Shire, northern New South Wales: plant communities, species and conservation. *Proceedings of the Linnean Society of New South Wales* 113: 203-243.

RICHARDSON, A.M.M. and SWAIN, R. 1980. — Habitat requirements and distribution of *Engaeus cisternarius* and three sub-species of *Parastacoides tasmanicus* (Decapoda: Parastacidae), burrowing crayfish from an area of south-western Tasmania. *Australian Journal of Marine and Freshwater Research* 31: 475-484.

RIEK, E.F. 1969. — The Australian freshwater crayfish (Crustacea: Decapoda: Parastacidae) with descriptions of new species. *Australian Journal of Zoology* 17: 855-918.

ROSS, A., DONNELLY, T. and WASSON, R. 1992. — The peopling of the arid zone: human-environment interactions. *In*: DOBSON, J. (ed.) *The Naive Lands*. Pp. 76-114. Longman Cheshire, Melbourne.

Saunders, D. 1993. — Habitat reconstruction: the revegetation imperative — an animal perspective. *Conserving Biodiversity. Threats and Solutions. 29th June — 2nd July. University of Sydney. Programme.* (abstract only).

STANISIC, J. 1994. — The distribution and patterns of species diversity of land snails in eastern Australia. *Memoirs of the Queensland Museum* 36: 207-214.

THOMSON, J.M., LONG, J.L. and HORTON, D.R. 1987. — Human exploitation of and introductions to the Australian fauna. *In*: DYNE, G.R. and WALTON, D.W. (eds). *Fauna of Australia. Volume 1A. General Articles.* Pp. 227-249. Australian Government Publishing Service, Canberra.

TILZEY, R.D.J. 1976. — Observations on interactions between indigenous Galaxiidae and introduced Salmonidae in the Lake Eucumbene catchment, New South Wales. *Australian Journal of Marine and Freshwater Research* 27: 551-564.

WATER RESOURCES COMMISSION, NEW SOUTH WALES. 1986. — *Water and the Natural Resources of New South Wales.* W.R.C.N.S.W., North Sydney.